designed for 40 GHz but availability is really a question of demand at either 28 GHz or at 40 GHz. A helical tube design, such as that employed by Varian for the 100 Watt TWTA currently used in the Cellular Vision hub transmitter is capable of achieving 90-110 watts at 41 GHz. Coupled cavity implementations are capable of achieving much higher powers at 41 GHz. Surveyed TWTA manufacturers believe that the 40 GHz tube would be moderately more expensive, on the order of $14 K per unit (~ 20% higher cost) for quantities of several hundred.

Sector antennas used at the LMDS hubs are readily designed and constructed for 40 GHz and there should be no cost differential nor performance degradation compared to 28 GHz. Sidelobe and cross-polarization characteristics will be equivalent at both frequencies.

Subscriber antennas in the form of parabolic antennas are also available with the same performance and cost at either frequency. Array antennas are also feasible but since array antennas will exhibit some coupling losses at both frequencies, LMDS designers may find parabolic antennas to be a better choice[27]. However, even a multi-element array antenna can be used since any decrease in efficiency can be compensated for by a practical increase in the gain of the hub antenna.

Components are readily available for implementation of subscriber receivers that provide the same 6 dB noise figure that Suite 12 has adopted

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27 We are aware of a development of a "leaky-wave" flat plate antenna which will operate at dual frequencies of 44 and 20 GHz and achieve an efficiency of 55%. Production of a single frequency antenna to satisfy LMDS requirements would be more simple.

for its 28 GHz design. The RF portion of the receiver is estimated to initially be no more than 20% higher at 40 GHz than at 28 GHz.

Solid state components are readily available to generate the low power levels needed for subscriber transmitters in a two-way LMDS system implementation.[28]

V. THE COMMISSION SHOULD NOT BE MISLED BY CELLULARVISION'S CLAIMS

CellularVision submits, in Appendix 2 to their comments, an analysis that portends to support their contention that LMDS is not viable at 40 GHz. The facts, as related previously and in what follows, contradict many of the statements and apparent conclusions drawn by the CellularVision analysis.

We have shown that a 40 GHz LMDS system can be constructed that requires no more hubs than a system at 28 GHz without increasing transmitter powers. The CellularVision claim that 7 times more cells are required at 40 GHz is based upon hardware performance assumptions that are far below what is actually achievable at 40 GHz and at a cost which is within 20% of 28 GHz hardware.

We have shown that the components needed to build LMDS at 40 GHz are readily available. This showing is supported by the overwhelming comments submitted in response to the NPRM by industry. CellularVision's claims that 40 GHz TWTs are limited to 45 watts and that 40 GHz low noise amplifiers would have noise figures of 8 dB must be contrasted to our

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28 See, for example, the comments of Hewlett-Packard that solid state devices are available today that will provide powers of close to 1 watt at 40 GHz.

findings that 90-110 watt TWTs and receivers with 6 dB noise figures are very practical.

CellularVision claims that component costs for a 40 GHz LMDS system will be double the component costs for a like quantity of cells at 28 GHz. We have shown in our analysis that most components are identical at both frequencies. Only the TWT used as the hub transmitter and the RF section of the subscriber receiver will initially cost more at 40 GHz, on the order of 20% for these specific components which will have little influence on the overall costs to install an LMDS network.

Attenuation by foliage at 40 GHz is said by CellularVision to prohibit implementation of LMDS. Signal attenuation through foliage at 28 GHz will in fact be in the range of 12-35 dB for a single tree in leaf. If foliage will prevent implementation of LMDS at 40 GHz, where it will only be approximately 1 dB greater than at 28 GHz for that single tree, it will also prevent implementation of LMDS at 28 GHz[29]

CellularVision claims that there will be a drastic reduction in specular reflections at 41 GHz which will result in a drastic reduction in the power level of the reflected signals.[30] Yet the measurements that NASA performed of reflected signals and reported in our comments showed that the magnitude of reflected signals at 41 GHz is within a few dB of those at 28

29 See "Attenuation of Radio Signals by Foliage" Negotiated Rulemaking Committee Document No. JTSG/4.1

30 See CellularVision comments at p.9 of Appendix 2.

GHz. Twenty-eight GHz has no special properties when it comes to being able to serve non line-of-sight subscribers.

Much is made by CellularVision of the lower point rain rates experienced in Europe compared to those in the United States. The point rain rates cited by CellularVision are in error. In Europe the rates range between 6 and 15 mm/hour and not between 3 and 7 mm/hour. In the United States, point rain rates range between 3 and 35 mm/hour, not 6 to 35 mm/hour. The high rain rate regions in the United States are found only in part of the southeast and there both 28 GHz and 40 GHz systems would be equally affected. The cell size would have to be significantly reduced at 28 GHz to achieve high signal availability in Crane rain climatic regions D_3 and E. A 40 GHz system could function equally as well in the same cell that is suitable for 28 GHz.

Rather sweeping conclusions are drawn by CellularVision based on the design of the European version of LMDS (Multipoint Video Distribution Systems or MVDS) which will be brought into operation this year. We note that the channel plan selected for Europe is based on the same bandwidths and interleaved channels having opposite polarizations as used in the ITU Region 1 BSS plan in order to be compatible with European standards. The choices were not necessary in order to achieve greater processing gain as claimed by CellularVision. The cross polarization characteristics and antenna sidelobe performance will be every bit as good at 41 GHz as at 28 GHz. There is no implication from the European MVDS design that any additional spectrum is required for LMDS at 41 GHz as compared with 28 GHz. There is no basis for the CellularVision claim that four times the spectrum would be required at 41 GHz. In fact, no additional spectrum is needed. We note that the U.K. system currently planned for implementation this summer is digital rather than FM to take advantage of modern technology. The CellularVision concern for wasteful spectrum efficiency[31] is particularly noteworthy in view of their insistence on use of old FM technology while digital technology could accommodate LMDS in one-fourth to one-half the spectrum needed for an FM implementation.

CellularVision stresses the fact that there are no 40 GHz LMDS systems in operation today. The conclusion they draw, that this is due to lack of viability, is false. The U.K. will put such a system into operation this very year and it will have the advantages that come with use of modern digital technology.

Finally, we must draw attention to the CellularVision contention that proof of the non-viability of fixed terrestrial systems above 40 GHz is an ITU "recognition" resulting in primary allocations above 40 GHz being assigned to satellite services.[32] The International Table of Frequency Allocations, however, clearly provides a large number of bands allocated for the fixed service between 40 GHz and 275 GHz.

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31 CellularVision comments, p.4 of Appendix 2.

32 Ibid. at p. 20 of Appendix 2.

VI. UNIFORM INTERNATIONAL ALLOCATIONS WILL SERVE THE PUBLIC INTEREST

Uniformity of U.S. and international allocations would yield benefits to U.S. industry in the form of easier market entry in other countries and benefits in the form of lower costs to the American public that would be derived from the economies of scale. The potential to produce products at lower unit costs would also benefit the competitiveness of American industry in international markets. Uniform allocations already exist throughout the world for the fixed-satellite service in the 27.5 -29.5 GHz band. This situation should not be allowed to change through adoption of alternative allocations in the United States. Without a worldwide allocation, global fixed-satellite and mobile-satellite systems will be impossible. We believe that this result would be a tragedy. Likewise, a second international market can be opened with the same potential advantages if a common frequency band is allocated for LMDS in the 40.5-42.5 GHz band where an allocation is already in place in Europe.

A number of comments were submitted by industry that support the benefits that common worldwide allocations can produce.

AT&T states:

> In addition to opening up the millimeter wave spectrum to commercial use, the Commission should do everything it can to achieve similar allocations of that spectrum internationally[33]

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33 See AT&T comments at p.5.

General Motors argues for a common band for vehicular radars in the United States and Europe for the same reasons as given above[34].

Hewlett-Packard says:

> Also, it should be pointed out, international coordination of regulatory efforts is mandatory from the point of view of American companies that wish to produce products for sale abroad, We hope that the proposals synthesized during the comment period will be given a thorough review for international compatibility, so that our radio regulations do not become de facto trade barriers.[35]

Rockwell International Corporation and the Telecommunications Industry Association (TIA) and others submitted similar comments.

It must be clear to the Commission that uniformity of allocations throughout the world is an important consideration as it prepares to adopt rules for frequencies in the millimeter wave region of the spectrum. The allocation for the fixed-satellite service in the 27.5-29.5 GHz band should be maintained and the 40.5-42.5 GHz band should be allocated for LMDS. Only this can provide the American public and U.S. industry with a win-win opportunity to establish and participate in new markets that both the satellite industry and LMDS can provided.

VII. ALLOCATION CHANGES IN THE FREQUENCY RANGE BETWEEN 50.2 GHz AND 71 GHz SHOULD BE CONSIDERED TO ACCOMMODATE KNOWN REQUIREMENTS

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34 Comments of General Motors at 22.

35 See Hewlett- Packard comments at 2.

The Commission has received comments that contain proposals to allocate additional or alternative frequency bands to those contained in its NPRM. In addition, some comments advocate higher e.i.r.p. limits than those proposed in the NPRM. There is now the need to rationalize the proposals and to optimize the potential to accommodate the requirements of all services in the frequency bands above 40 GHz.

The frequency range from 50 to 65 GHz is of particular interest to the Earth environmental science and meteorological communities because of the presence of unique atmospheric oxygen absorption lines that are located in this region of the spectrum. Spaceborne passive sensor measurements in the vicinity of these lines are used to develop atmospheric temperature profiles. Judicious selection of the measurement frequencies determines the altitudes in the atmosphere at which temperature measurements are obtained. Recognizing the value of this singular scientific resource, WARC-79 allocated the bands 50.2-50.4 GHz and 51.4-59.0 GHz to the Earth exploration-satellite (passive) service to be used to obtain data for weather forecasting and climate studies. Some of these allocations, specifically 50.2-50.4 GHz and 54.25-58.2 GHz, are shared with active radio services. Sharing studies prior to the 1979 WARC, based on characteristics for as yet undeveloped equipment extrapolated from similar equipment in lower bands, indicated that sharing should be feasible. Actual developments since 1979 have deviated from these projections with the result that certain adjustments in allocations to optimize use of this spectrum for the benefit of all of the allocated services would be in order.

Developments in atmospheric temperature measurements

Meteorological organizations have advanced the science of measurement of atmospheric temperature between 1979 and 1995. They have found that the allocations in the range of 50.2-66 GHz are currently not optimum and cannot provide temperature data in the mesosphere. A band between 60.3 and 61.3 GHz has been identified as necessary for mesospheric temperature measurements. In addition, the 51.4-52.6 GHz band, currently allocated on an exclusive basis for passive sensing has turned out to be unnecessary for atmospheric temperature sounding.

A factor to be considered in assessing the potential for shared use of frequency bands is the development of new sensor technology. Introduction of "pushbroom" sensors is expected in the near future. This new class of passive sensor can achieve greater measurement sensitivity but is more susceptible to interference than conventional scanned sensors.[36]

Crosslinks between LEO fixed satellites

The band 54.25-58.2 GHz is shared among the Earth exploration-satellite (passive) service, the space research (passive) service and the fixed, mobile and inter-satellite (ISS) services. When the band was allocated for the ISS in 1979, it was envisioned that the ISS would consist of links between geostationary fixed-satellites and a few links between geostationary satellites and low orbiting

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36 Recommendation ITU-R SA.1029, "Interference Criteria for Satellite Passive Remote Sensing", specifies a permissible interference level of -166 dBW in a reference bandwidth of 100 MHz for pushbroom sensors in the frequency range of 50 to 66 GHz compared to -161 dBW for conventionally scanned sensors.

satellites. Today there are plans for crosslinks between low orbiting fixed-satellites with as many as 840 satellites in a single network. The conclusion that sharing is generally feasible between passive spaceborne sensors and the ISS is no longer valid. Spaceborne microwave passive sensors such as the Advanced Microwave Sounding Unit (AMSU), the first of which will be launched this year, would experience interference as much as 30 dB above its interference threshold in the presence of crosslinks between LEO satellites. Interference would occur every time the AMSU was located in one of the antenna crosslink beams of the ISS satellite and when the ISS satellite was in the AMSU antenna beam. The AMSU interference threshold would even be exceeded by interference radiated from the sidelobes of the ISS crosslink antenna into its antenna sidelobes when the two satellites are in close proximity to each other. The result would be an electromagnetic screen that would prevent acquisition of these vital environmental data.

Fixed service developments

In addition to evolving plans to implement LEO crosslinks on a very large scale, specifications are being prepared in Europe for fixed service systems in the 54.25-58.2 GHz band. As in the case of the ISS, the fixed systems are expected to be considerably different than foreseen in 1979. The specifications under consideration include local connections and supporting infrastructure for large-scale mobile networks with orders of magnitude more transmitters than the radio relay systems anticipated in 1979 projections. The compatibility of passive sensors, including AMSU, with fixed service systems such as those now being specified has been studied by the Conference of European Posts and Telegraphs (CEPT) and the Space Frequency Coordination Group (SFCG). Both the CEPT project team[37] and the SFCG[38] found incompatibilities in certain frequency ranges that would require constraints on fixed service parameters to resolve. Both groups recommend some realignment of allocations to insure that there is no interference to the passive sensor operations while avoiding constraints on the characteristics of the evolving fixed systems. The Telecommunications Industry Association (TIA) has proposed reallocation of the 48.5-51.4 GHz and the 55.2-58.2 GHz bands for exclusive use by private and common carrier fixed point-to-point microwave users[39]. We oppose this use because the 50.2-50.4 GHz band and the 54.25-56 GHz band are bands where incompatibilities have been identified and they are overlapped by the bands proposed by the TIA. We offer below an alternative that should satisfy the requirements of all users of this spectrum. We note in passing our understanding that the planned use of the 54.25-57.2 GHz band in Europe is not for traditional point-to-point links but to provide point-to-multipoint infrastructure in large-scale mobile networks including PCN or other networks based on micro cells which will require large numbers of links[40].

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37 Final Report, CEPT SE20, September, 1994.

38 SFCG Recommendation 14-3-2 (provisional), Use of the Band 50.2-66 GHz by Passive Sensors on Earth Exploration Satellites, September, 1994.

39 TIA comments at B. on p.10.

40 Final Report of CEPT SE20, September, 1994.

Compatibility between passive sensors and terrestrial transmitters in the vicinity of 60 GHz

In our comments, we analyzed the potential for interference to passive sensor mesospheric measurements using the 60.3-61.3 GHz band that might be caused by the proposed allocation in the 59-64 GHz band for unlicensed devices and have found these uses to be compatible. Our finding was based on the Commission's proposal that unlicensed devices (except vehicular radars) be limited to a peak power density of 200 nanowatts/cm^2 at a distance of 3 meters from the antenna. As pointed out in the NPRM, this power density is comparable to an e.i.r.p. of 0.25 w.

Hewlett-Packard and others have proposed that the e.i.r.p. limit for unlicensed devices in the 59-64 GHz band be increased over the level proposed in the NPRM[41]. We believe that some increase in e.i.r.p. could be introduced while still assuring that passive spaceborne measurements can be obtained in this unique region of the spectrum. The e.i.r.p. limit of +10 dBW for unlicensed devices would appear to be suitable.

Hewlett-Packard also proposes additional licensed bands between 56 GHz and 58.2 GHz accompanied with an e.i.r.p. limit of +16 dBW. We believe that this proposal is a good one that preserves the oxygen absorption bands for those applications that require the unique properties of this spectrum. We would, however, suggest that appropriate limits be adopted for off-axis e.i.r.p. at high elevation angles in order to insure interference free operation of spaceborne

41 Hewlett-Packard suggests an e.i.r.p. limit of +10 dBW for unlicensed devices in the 59-64 GHz band.

because the atmospheric attenuation is so great as to accommodate sharing without constraints on either the fixed service or on passive sensor operations[45].

We support these allocation change proposals. It is timely to rationalize allocations in the range of 50.2-71 GHz to bring them into harmony with the needs of the services that use these bands. A realignment can accommodate real developments that have taken place since 1979 and optimize efficient use of the spectrum. The Commission's NPRM for commercial development and use of a portion of the millimeter wave frequency bands above 40 GHz is an opportune time to begin consideration of these other needed allocation changes. Domestic consideration of realignment of allocations in the 50.2-71 GHz frequency range must, of course, be coupled with international consideration since the space systems operate around the globe. The 1997 WRC presents a timely opportunity for this to occur.

To summarize, we believe that the following allocation realignments in the 50.2-71 GHz range would enable interference-free atmospheric temperature measurements of vital importance to understanding the world's weather and climate while removing any need for constraints on the parameters of the emerging fixed and inter-satellite systems that will use frequencies above 40 GHz:

- provide exclusive allocations for the Earth exploration-satellite (passive) service in the currently shared bands between 50.2-50.4 GHz and 54.25-56 GHz;
- make an allocation to the Earth exploration-satellite (passive) service in the band 60.3-61.3 GHz;

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45 We note with interest that Hewlett-Packard has taken note of the SFCG recommendations and has tailored its proposals to be compatible with passive sensor operations.

- move the current ISS allocation in the 54.25-58.2 GHz band, except for the small band from 56.9-57.0 GHz which is required for use by existing Government non-LEO ISS systems, into the range 65-71 GHz;

- limit ISS use of the band 60.3-61.3 GHz to systems other than crosslinks between LEO satellites;

- share the currently exclusively passive band 58.2-59 GHz between the Earth exploration-satellite (passive) service and the fixed and mobile services;

- when the foregoing actions have been completed, delete the Earth exploration-satellite (passive) service from the band 51.4-52.6 GHz in favor of allocations to the fixed and mobile services.

VIII. INTERCHANGE OF ALLOCATIONS IN THE BANDS 78-79 GHz AND 94-95 GHz WOULD BENEFIT DEVELOPMENT OF SPACE BASED CLOUD SENSING RADARS

WARC-79 allocated the 78-79 GHz band for use by active spaceborne sensors[46]. The requirements for this band were based principally on its intended use for cloud monitoring radars.

The effect of clouds on the climate is one of the major uncertainties in predicting the change in climate due to increased greenhouse gasses. Global observations of the vertical structure of clouds are needed and these can only be obtained through use of spaceborne radars. Although it has only been in recent years that development of spaceborne cloud monitoring radars has started in earnest, rapid development of spaceborne cloud radars is now being pursued in the United States, the European Space Agency (ESA), Japan and the United Kingdom.

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46 Radio Regulation 912: "In the band 78-79 GHz radars located on space stations may be operated on a primary basis in the earth exploration-satellite service and the space research service".

The present development work has revealed that 78-79 GHz is not a very good band for spaceborne cloud radar for a variety of reasons. The reflectivity of marine stratus clouds, which are very important to the radiation budget, may have a reflectivity of -30 dBZ, 70 dB below the reflectivity of rain. Scattering from clouds at millimeter wavelengths increases as the frequency raised to the fourth power because of the small size of cloud particles which fall in the range of 10-100 microns. Due to this frequency dependency, the backscattered signal available to a radar at 94 GHz is twice that at 79 GHz. The increase in signal turns out to be crucial to mission success because the required sensing threshold to measure clouds having a reflectivity of -30 dBZ at 79 GHz is below that achievable with available technology. An integration time 4 times longer would be required at 79 GHz compared to 94 GHz in order to preserve the same signal-to-noise ratio. It would be necessary to degrade either the aerial coverage or the spatial resolution to the point that the mission objectives would be seriously degraded. A second advantage of 94 GHz for cloud radars is a 20% better resolution compared to 79 GHz for the same antenna aperture.

A third reason 95 GHz is preferred is the extensive data base that has been developed from ground and aircraft measurements at 95 GHz. The usefulness of this data base would be seriously compromised were the spaceborne radar to be operated at a different frequency. Operations have been carried out at 95 GHz because there is existing radar equipment at 95 GHz while there is currently none at 78 GHz.

Both 76-81 GHz and 92-95 GHz are allocated to the radiolocation service on a primary basis. The fixed, fixed-satellite and mobile services are also allocated in the 92-95 GHz band on a primary basis. The amateur and amateur-satellite services are also allocated in the 76-81 GHz band on a secondary basis.

We propose a realignment of the allocated services in the 76-81 GHz and 92-95 GHz bands that will enable development of spaceborne cloud radars. We propose that the allocation for active sensors in the 78-79 GHz band (RR 912) be deleted in favor of an allocation to the Earth exploration-satellite (active) service in the 94-95 GHz band. We further propose that the fixed, fixed-satellite and mobile services be transposed from 92-95 GHz to within the 76-81 GHz band and that the amateur and amateur-satellite services be transposed into the 92-95 GHz band.
The issue of a suitable frequency for cloud radars has also been addressed in the SFCG where the proposals presented above were endorsed[47].

Proposed allocation for vehicular radars in the 94.7-95.7 GHz band

We note the proposal in the NPRM to allocate 94.7-95.7 GHz for vehicular radars on an exclusive basis. The responses to the NPRM include essentially unanimous support for exclusive allocations for vehicular radars. Comments to that effect included those submitted by Hewlett-Packard, General Motors, the American Automobile Manufacturers Association, the Millimeter Wave Advisory Group and others. This proposal is not compatible with our proposal to operate cloud radars in the 94-95 GHz band. We have no reason to believe that cloud radars and vehicular radars would be incompatible because sharing can be considered to be feasible, in general, between the radiolocation service and the Earth exploration-

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47 See Space Frequency Coordination Group Resolution 14-5, "Necessity of the 94-95 GHz Band for Active Sensors for Earth Exploration Satellites".

and meteorological-satellite services (active sensing)[48]. The analysis of suitable sharing criteria at 76 GHz provided by the General Motors Corporation and GM Hughes Electronics supports the belief that spaceborne active sensors would be compatible users of common frequencies[49]. The cloud radar characteristics include use of a 2 m diameter antenna pointed at nadir, a peak transmit power of 1 kW and a duty cycle of 1.5%. Of course, we appreciate the Commission's desire to avoid any possibility of interference to vehicular radars and this approach could readily be preserved if the allocated band for vehicular radar were to be shifted up in frequency by 300 MHz into the band 95-96 GHz.

IX. CONCLUSIONS

For the reasons set forth in our Comments and Reply Comments NASA urges the Commission to:

- Take advantage of this NPRM to resolve the problems surrounding its proposals to establish an LMDS under CC Docket No. 92-297 by designating 40.5-42.5 GHz for LMDS in lieu of 27.5-29.5 GHz;

- Coordinate decisions of this NPRM and the NPRM issued under CC Docket No. 92-297 to give the American public and American industry a win-win opportunity to establish and participate in new markets that both the satellite industry and LMDS can provide;

- Delay decisions in CC Docket No. 92-297 until allocations for LMDS above 40 GHz have been established in the instant rulemaking;

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[48] See Recommendation ITU-R SA.516-1, "Feasibility of Sharing Between Active Sensors Used on Earth Exploration and Meteorological Satellites and the Radiolocation Service".

[49] See Appendix B, "Initial Analysis of a Sharing Criteria at 76 GHz" in the General Motors and GM Hughes Electronics comments.

- Adopt allocations and rules in the frequency range from 50.2 GHz to 71 GHz that will protect use of the unique oxygen absorption lines of vital importance for spaceborne passive remote sensing without constraining the characteristics of fixed, mobile and inter-satellite systems, and;

- Either shift the proposed band for vehicular radars from 94.7-95.7 GHz to 95-96 GHz or permit the 94.7-95 GHz band to be used by both vehicular radars and active spaceborne sensors in the Earth exploration-satellite and space research services.

Respectively submitted,

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